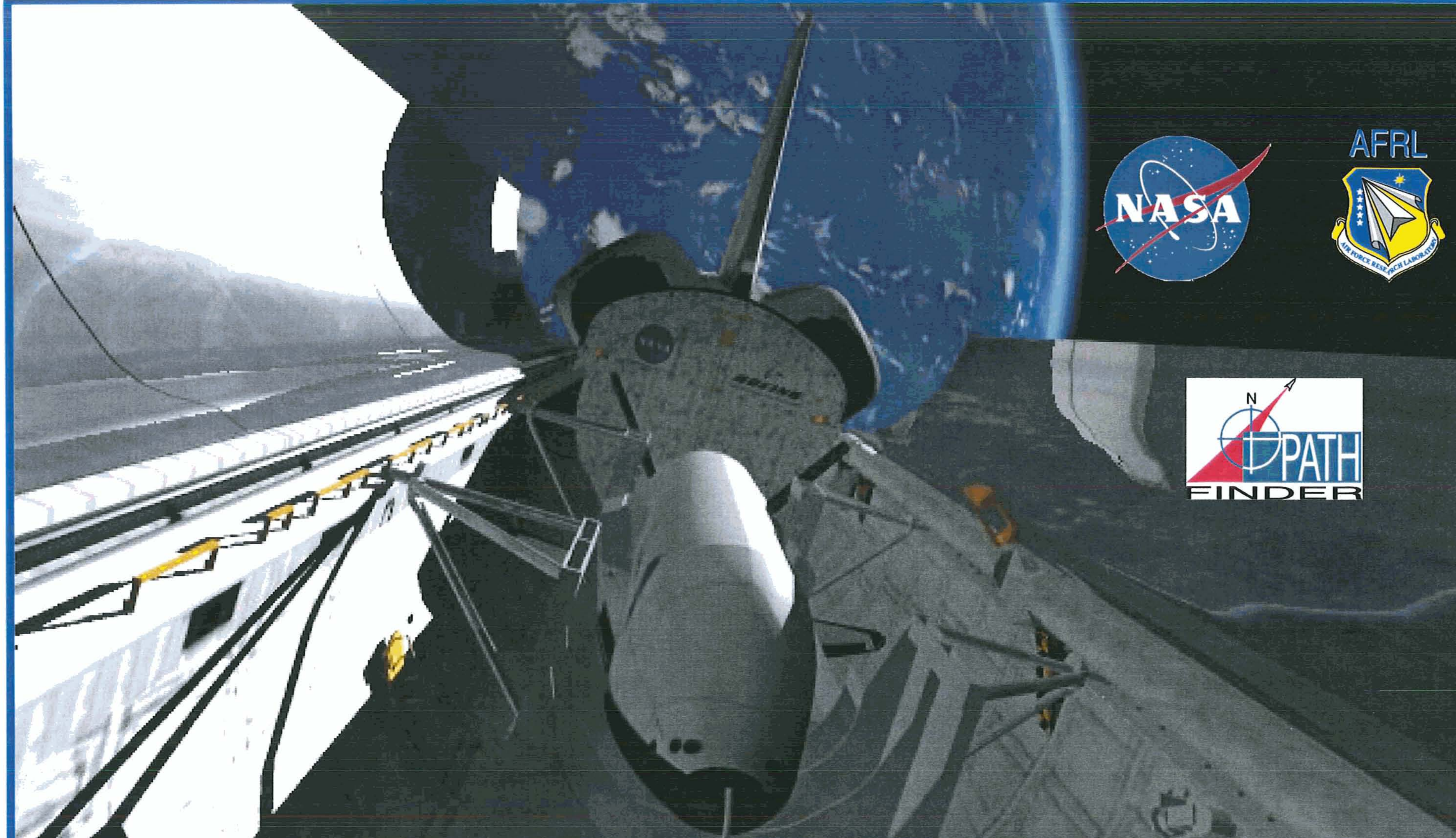
Boeing X-37



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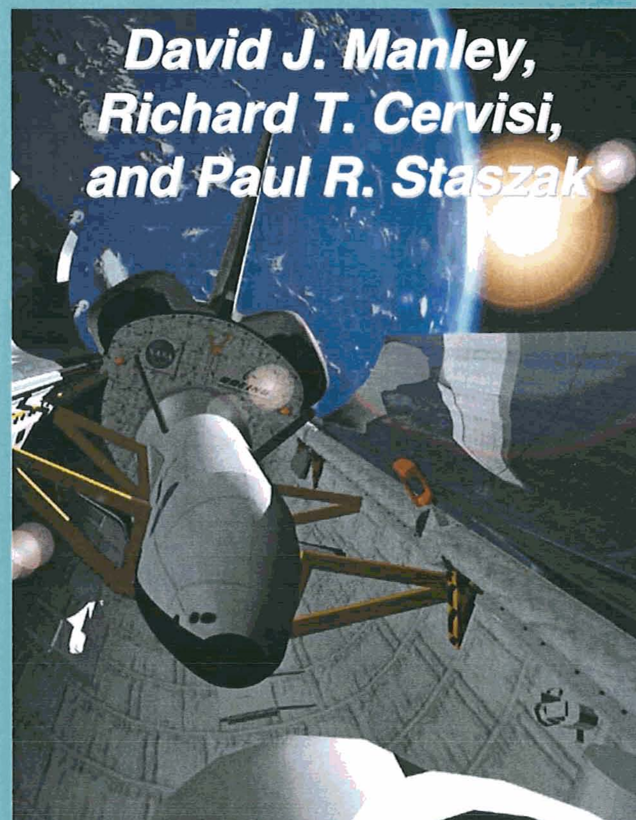
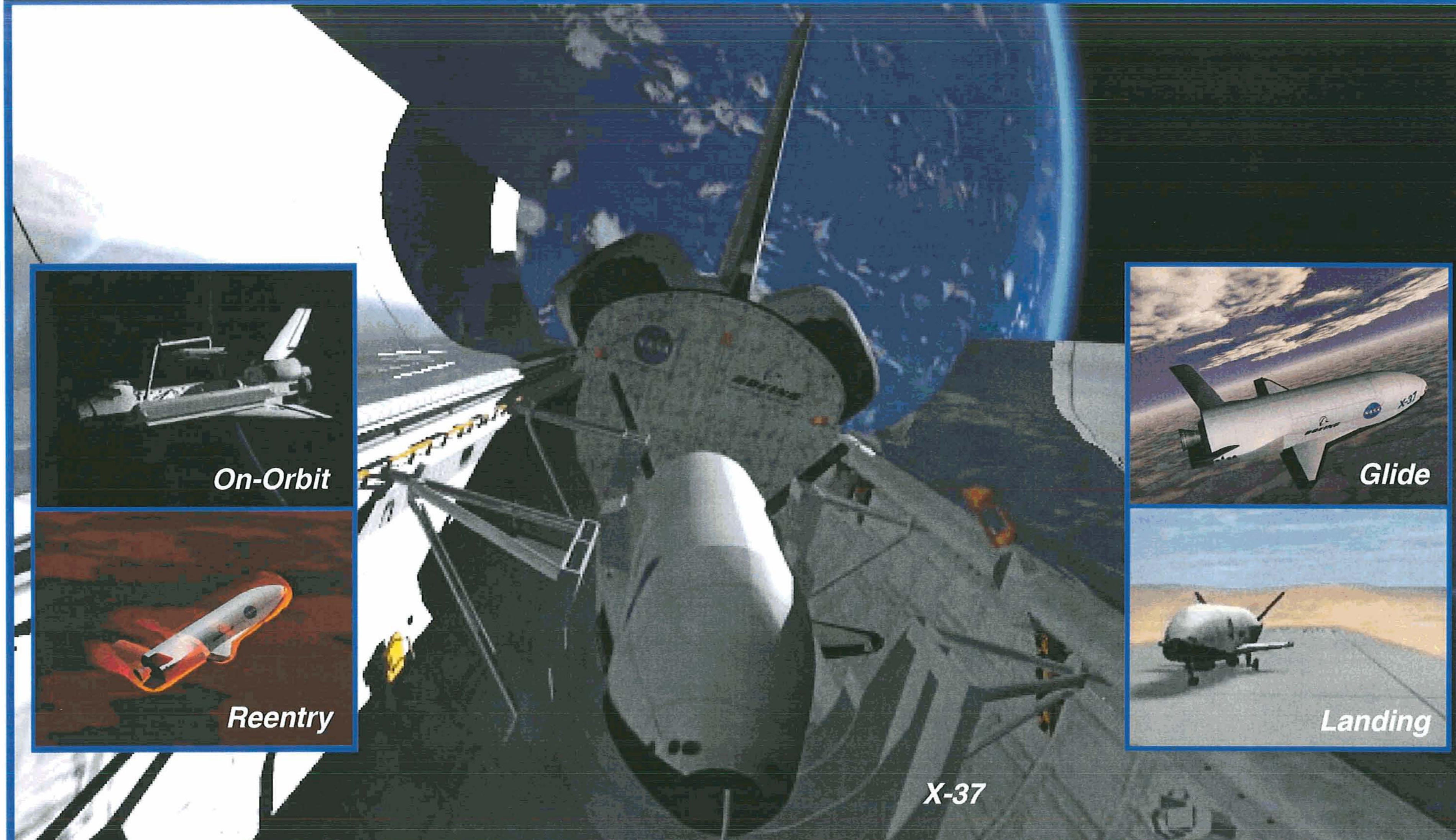
How X-37 Technology Demonstration Supports Reusable Launch Vehicles



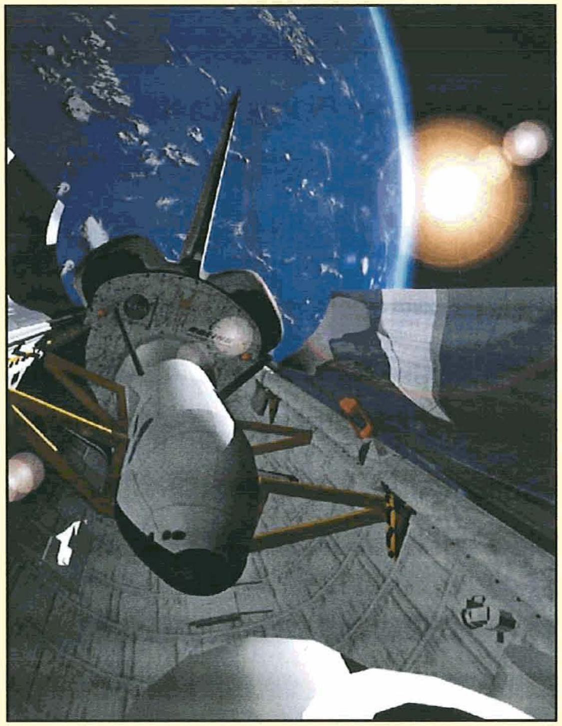
X-37 Program Objectives

- Mature the technologies for reusable space vehicles by performing ground and flight demonstrations.
    - Lower the cost for routine access to space.
    - Make next generation space transportation system commercially viable.
    - Enhance planning for future RLV space operations.
- Enable investor confidence in RLV systems.
- Achieve a technology readiness level of 8 (flight proven) for critical technologies.

X-37 Description

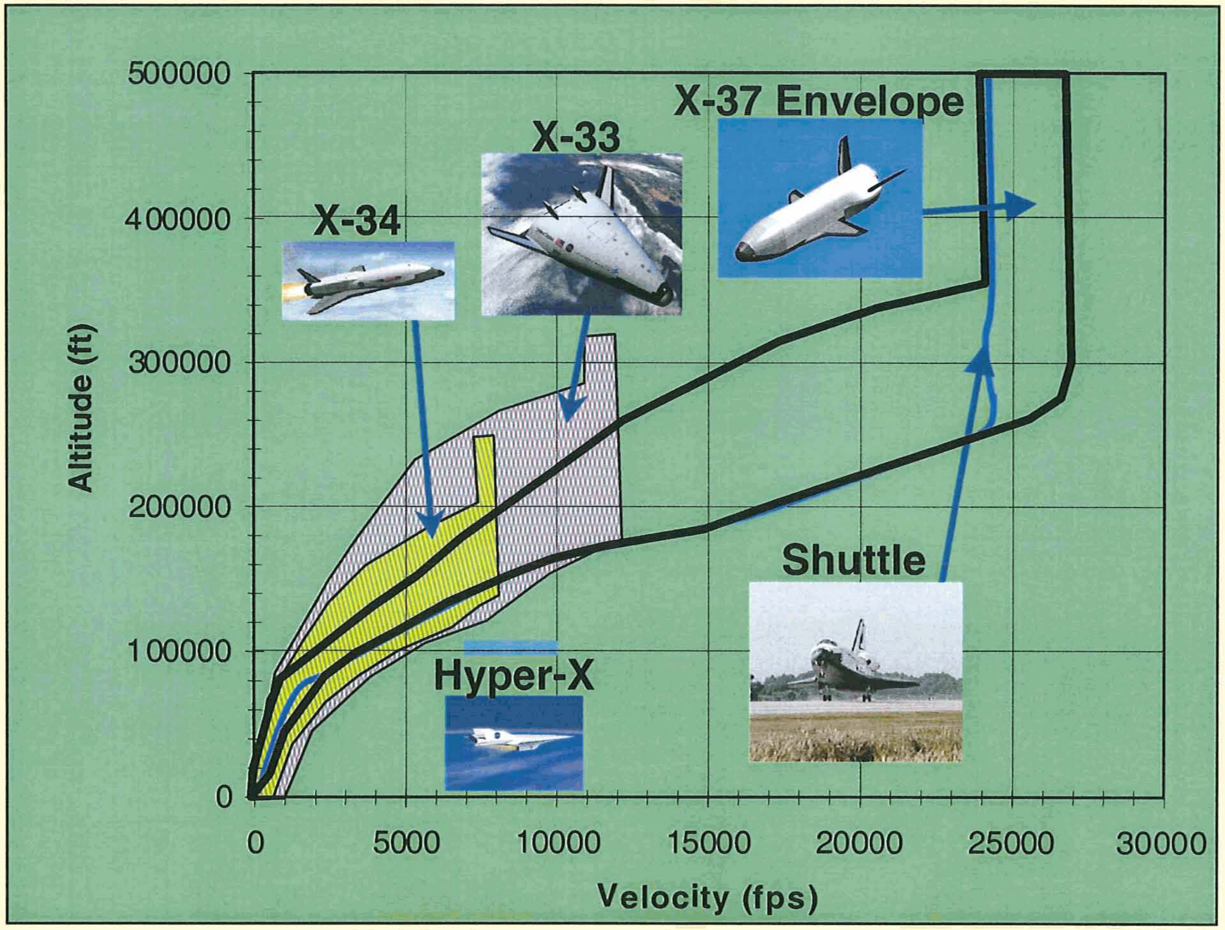


X-37 Vehicle Characteristics



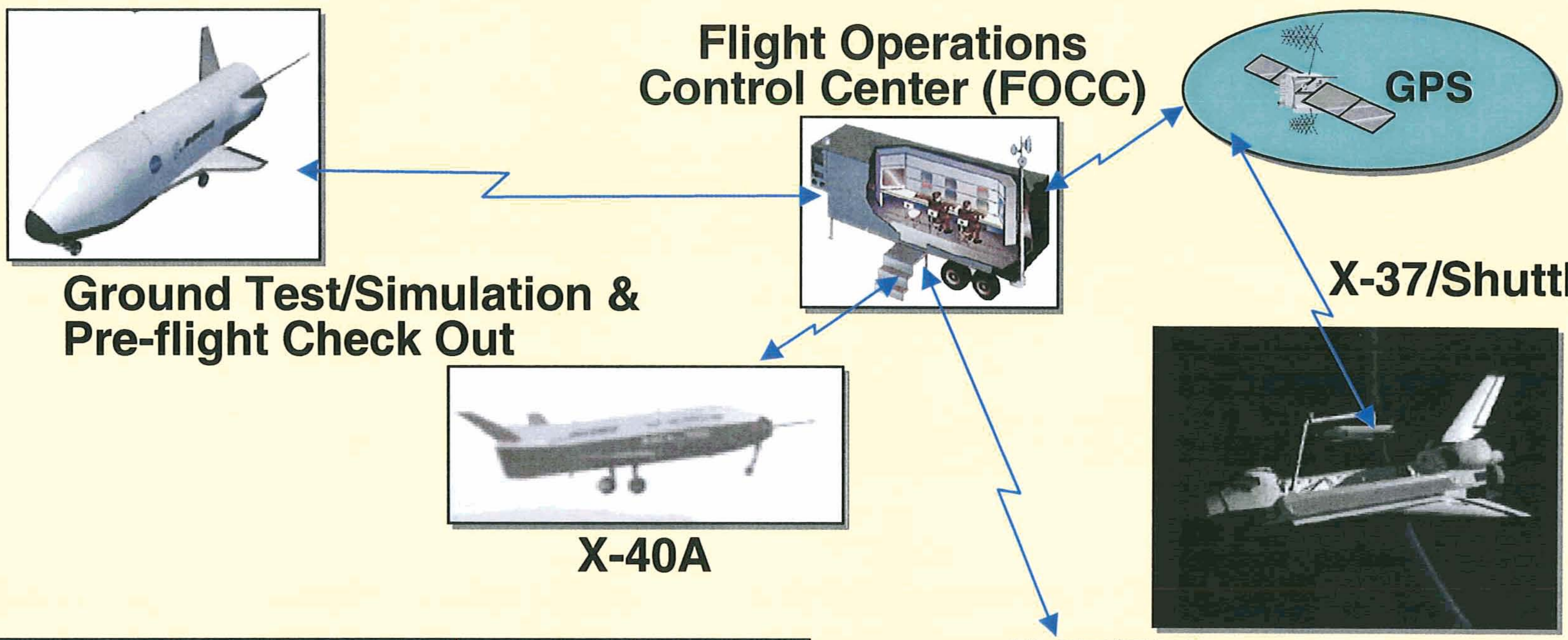
- The X-37 is 27.5 feet long – about half the length of the Shuttle payload bay – and weighs about 6 tons. Its wingspan is about 15 feet, and it contains an experiment bay 7 feet long and 4 feet in diameter.
- After the X-37 is deployed from the Space Shuttle Orbiter, it can remain in orbit up to 21 days, performing a variety of experiments before reentering the atmosphere, gliding to earth and landing on a conventional runway.
- The vehicle provides a platform for both operational and experimental technologies in both on the vehicle and within the payload bay.

X-37 Expands the Testbed Envelope to Orbital Capability



- X-34 atmospheric flights up to Mach 8.
- Hyper-X atmospheric flights up to Mach 10.
- X-33 atmospheric flights up to Mach 12.
- X-37 orbital flights up to Mach 25.

Overview of X-37 Flight Test Program



Test Category	X-40A	X-37
Tow/Taxi	5	5
Captive Carry	3	3
Approach and Landing	7	5
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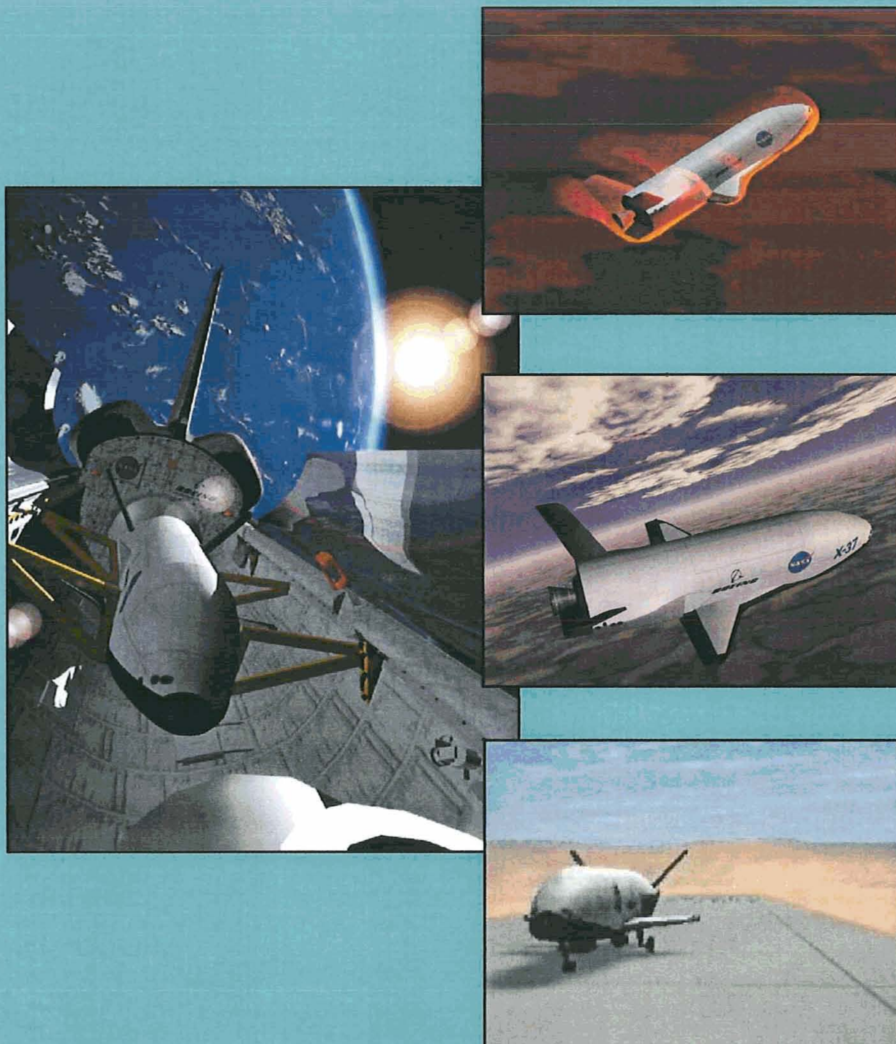
X-37/B52

Progressive Ground and Flight Testing In Multiple Environments

Thirty-Nine Technologies and Experiments are Being Demonstrated on the X-37

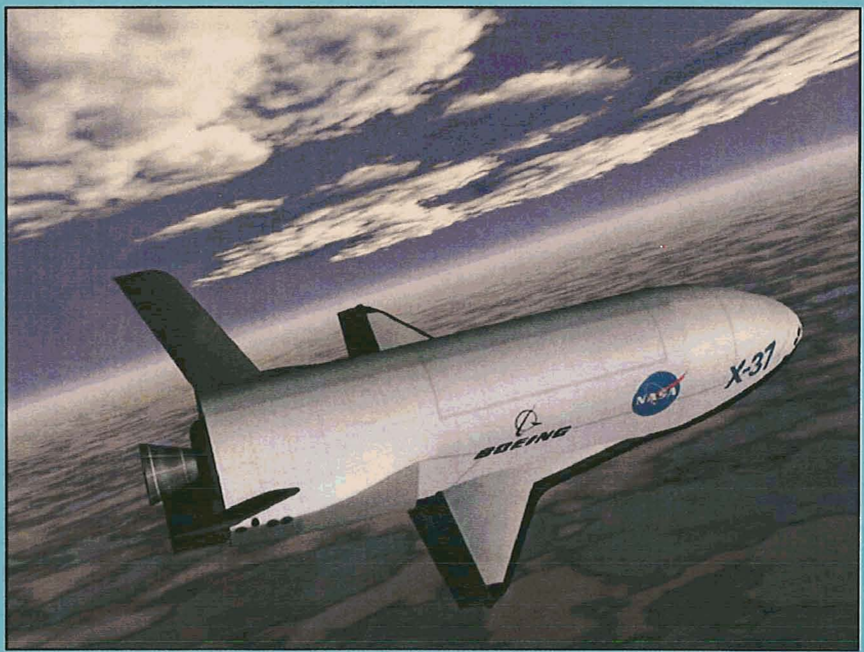


- Twenty-nine technologies are embedded in the baseline X-37.
  - Sixteen advanced vehicle technologies.
  - Thirteen advanced operations technologies.
- Eight NASA flight experiments are being flown on the X-37.
- Two Air Force flight experiments are being flown on the X-37.

X-37 Airframe/Structures Technologies

Technologies

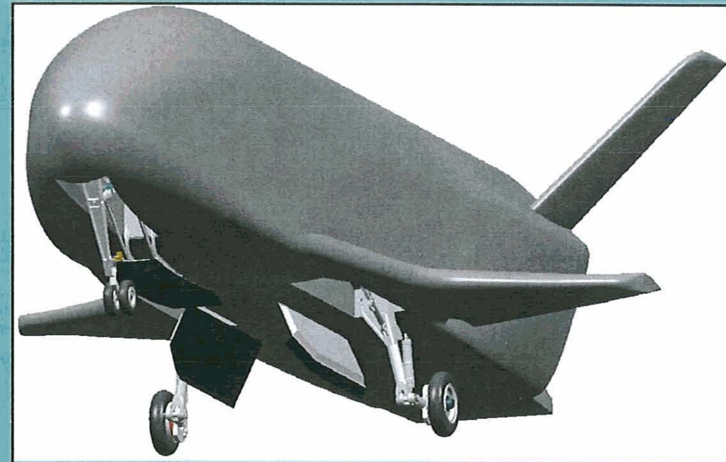
- High temperature composite structures.
- Carbon/silicon carbide materials on thin aerodynamic surfaces.
- A modular airframe that can accommodate rapid changeouts.
- Lightweight standardized payload experiment container.

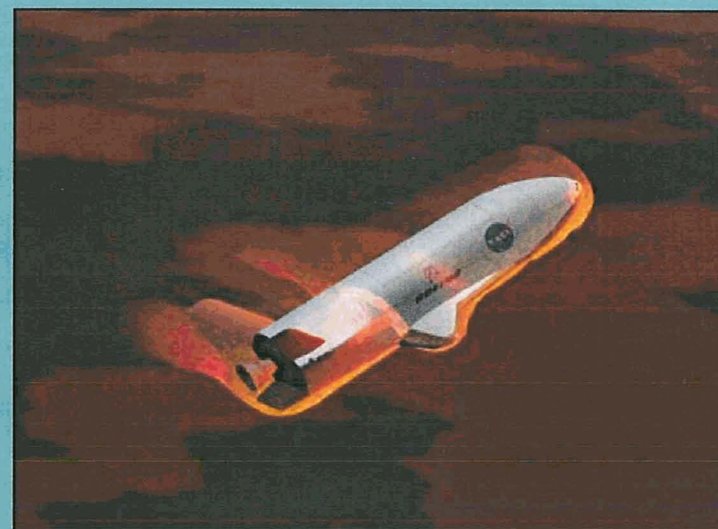


X-37 Mechanical, Propulsion, and Thermal System Technologies and Experiments

Technologies
- Hydrogen peroxide propulsion
  - Hydrogen peroxide/JP-8 main engine.
  - Hydrogen peroxide reaction control thrusters.
- Loop heat pipe thermal control.
- Lightweight landing gear and high performance brakes.
- Advanced TPS
  - Conformal reusable insulation blankets on "windward" surfaces.
  - High temperature blankets on sides and upper surfaces.
  - Tile leading edges.
  - High temperature seals.

Experiments
- Enhanced attitude control thrusters.
- Experimental TPS
  - Low density tile.
  - Metallic tile.
  - DurAFRSI.



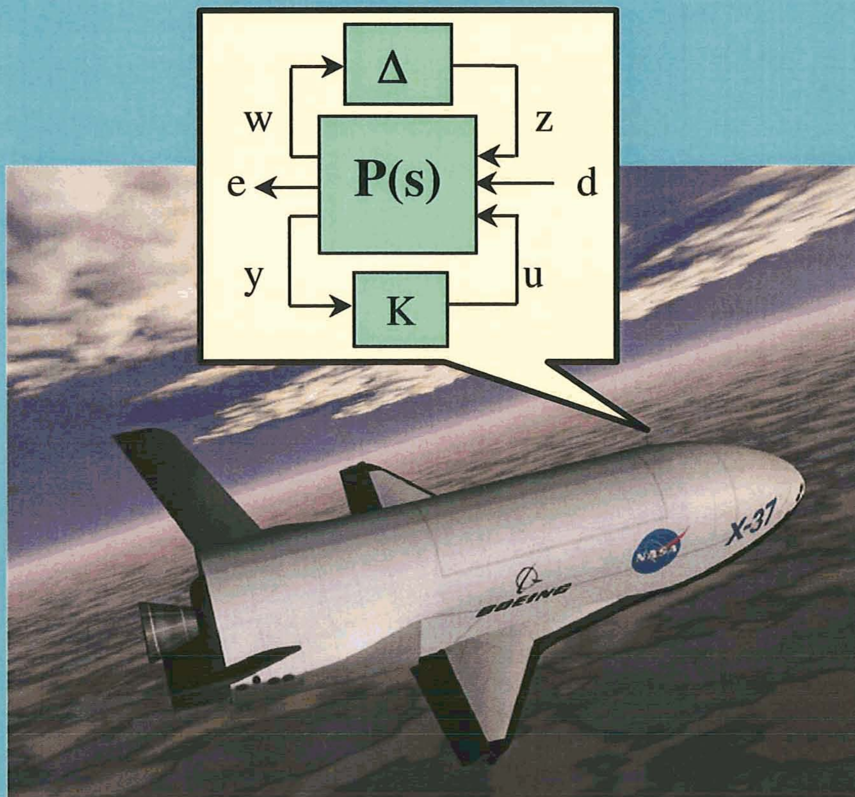


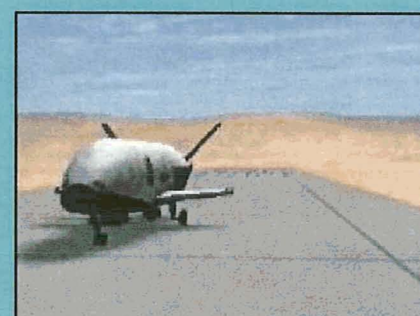
X-37 GN&C Technologies

The GN&C subsystem coordinates the control effectors to execute maneuvers as required by orbit or entry operations.

Technologies

- Calculated Air Data System (CADS) that uses on-board GPS and inertial navigation system data to determine airspeed, attitude, and altitude.
- Windward adaptive guidance that permits all-weather operations.
- Mission data load which reduces turnaround time.
- Crosswind landing capability for small reusable space vehicles.
- Automated rendezvous and proximity operations.

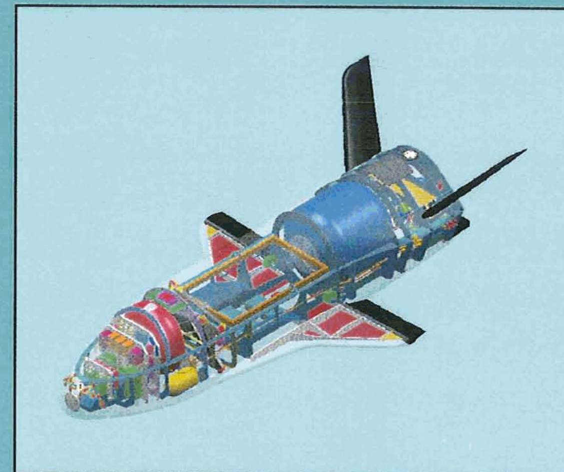


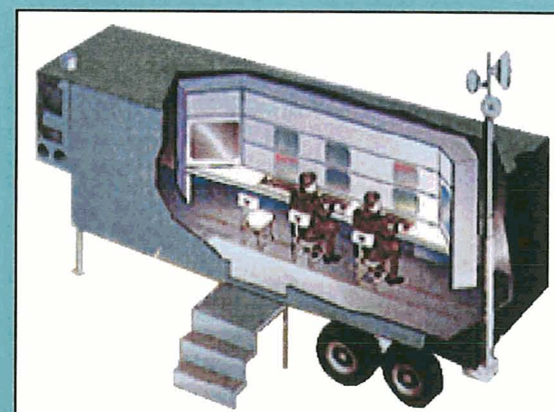


X-37 Avionics, Power, and Software Technologies and Experiments

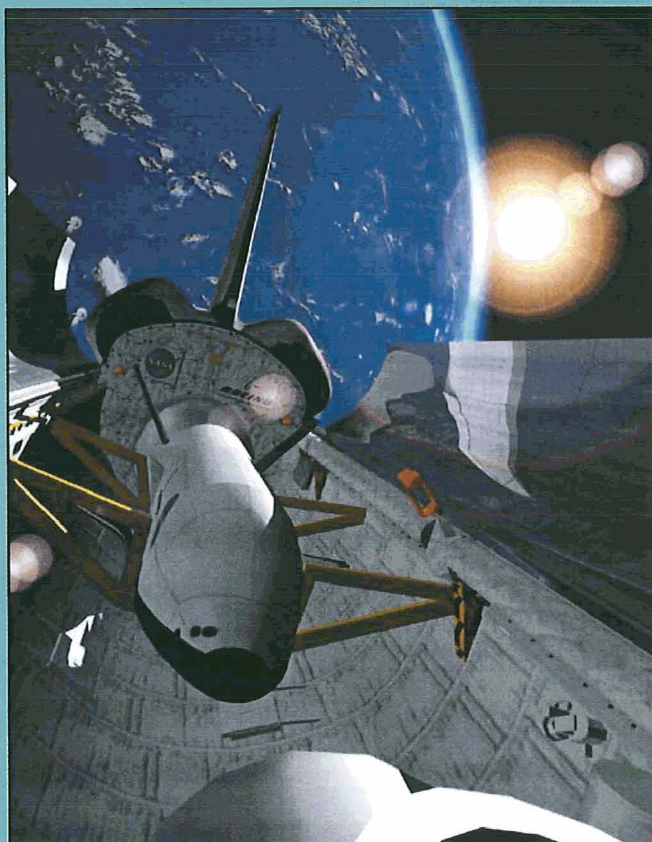
Technologies
- Fault-tolerant flight control system to enable autonomous operations.
- Open architecture for flight computing elements to readily accommodate future technology growth.
- Commercial-off-the-shelf hardware and software.
- A dual rate fiber optic bus which provides interfaces to docking controller, experiments, antenna and payload.
- A subsurface, electronically steerable, x-band antenna for high-data-rate communications.
- Small crew FOCC (Flight Operations Control Center).
- Advanced solar arrays that can be deployed in orbit during long duration flights, then stowed for reentry and landing.

Experiments
- High temperature electronics.
- High energy-density batteries.
- NASA IVHM (Integrated Vehicle Health Management) with Boeing IM (Informed Maintenance).
- NASA docking hardware controller.





X-37 Technologies and Experiments Support Reusable Launch Vehicle Needs



- NASA/AF Future X Pathfinder X-37 Program enables the maturation of reusable space transportation systems.
  - Technology demonstrations using on-orbit and reentry flight environments.
  - Targeting breakthrough areas in RLV operations and operability technologies.
  - Reusable 2nd stage of a two-stage-to-orbit (TSTO) RLV system.
  - Technologies support NASA and USAF Programs.

Program began July 1999.

Vehicle assembly begins November 2000.

First B-52 atmospheric flight test is in October 2001.

First Shuttle launched flight test is in September 2002.


Boeing X-37
NASA
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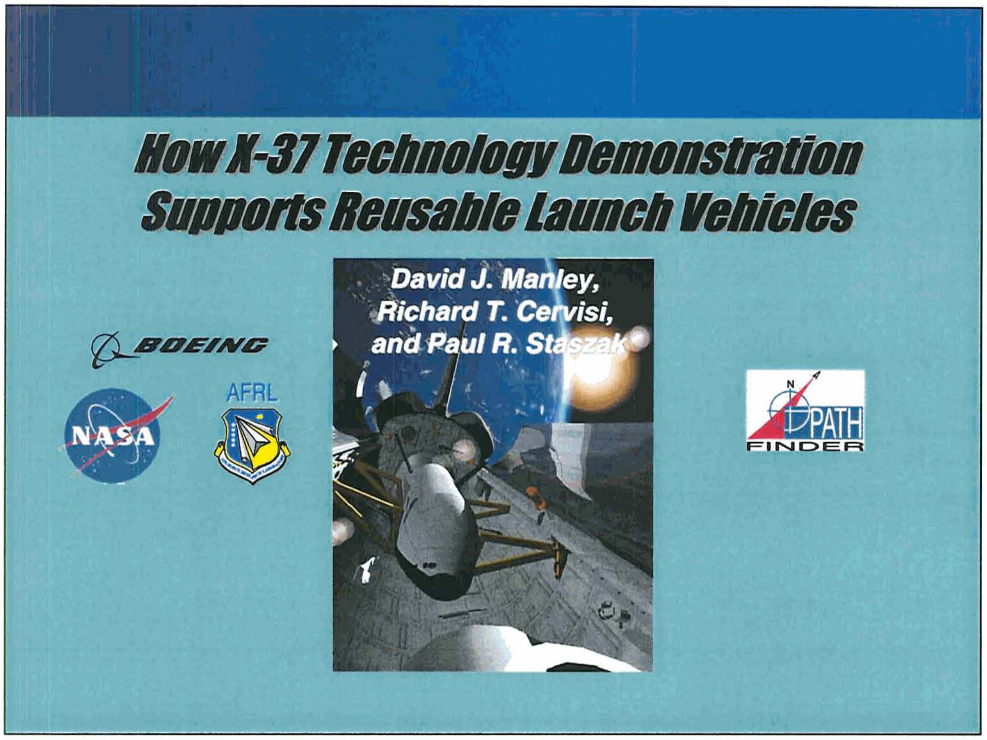

The Boeing advanced technology vehicle X-37 provides a high-value, flight-focused program capable of demonstrating ~~the broadest~~ a broad range of earth-to-orbit and on-orbit technologies ~~required to~~ focused toward dramatically lower the cost of space transportation. The X-37 represents a critical step in validating technologies and operations that enable new missions and markets involving reusable launch vehicles (RLV). The X-37 technologies matured as a result of the program ~~is traceable and scalable~~ are applicable to a broad class of vehicles supporting multiple architectures.

This presentation discusses how the X-37 technology demonstrations support reusable launch vehicle needs.

X-37 Program Objectives

- Mature the technologies for reusable space vehicles by performing ground and flight demonstrations.
  - Lower the cost for routine access to space.
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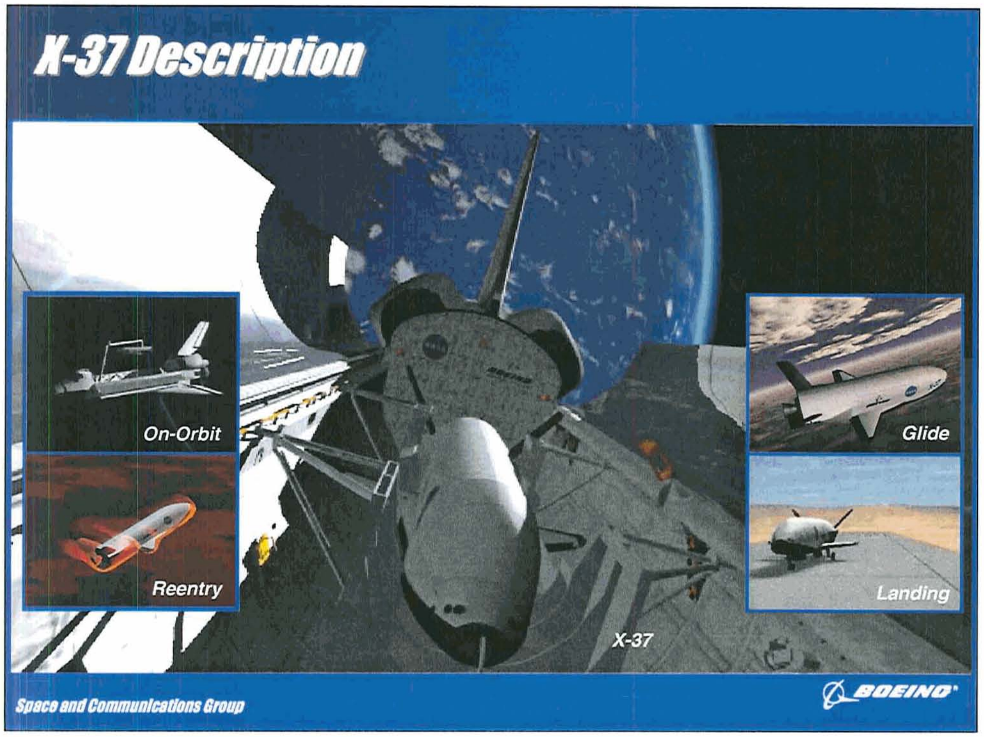
The X-37 is an advanced technology vehicle. As such, one of the primary objectives of the X-37 program is to mature key technologies for reusable space vehicles through ground and flight demonstrations. The expectation is through maturing the technologies that the cost of routine access to space will be lowered, next generation space transportation systems will become commercially viable, and future RLV space operations will be enhanced. A second objective is to enable investor confidence in RLV systems. A third is to increase the TRL level of critical technologies to level 8 (flight proven).

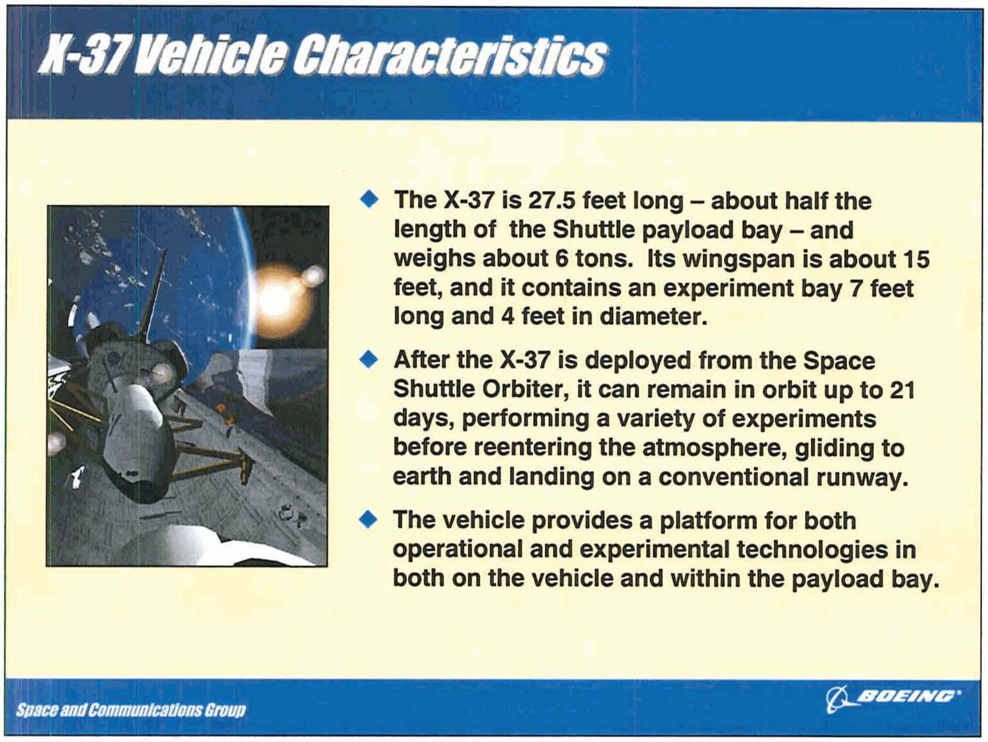


The X-37 program is focussed on a small, modular, technology-rich, orbit-capable vehicle derived from the successful X-40A Flight Test program. To complement other X-programs, the X-37 program provides three flight test environments: on-orbit, reentry, and landing.

The on-orbit environment provides the combined space environments of vacuum, zero-g, temperature extremes, and radiation required to demonstrate avionics architectures, hardware/software approaches, and ACS propellant system management. Using the X-37 for sensor and rendezvous and docking experiments provides an opportunity for future growth. Potential follow-on use of the Boeing X-37 vehicle upon completion of the NASA X-37 program could include use as a reusable satellite bus with a set of standard payload services to lower the cost of on-orbit experimentation. The X-37's capability to perform hypersonic maneuvers could permit exploration of aerobraking and aeroassist flight modes. Flight test environments for the X-37 could also permit additional demonstration of thermal protection system materials as well as future GN&C (guidance, navigation, and control) demonstrations to validate aeromanuevering technologies.

The reentry environment provides a real-world environment for maturing high-payoff technologies. The X-37 will provide a testbed for validating thermal protection system and high-temperature control surface technologies that require high-enthalpy, chemically reactive entry flow fields typical of reusable launch vehicles during high-Mach ascent and reentry.

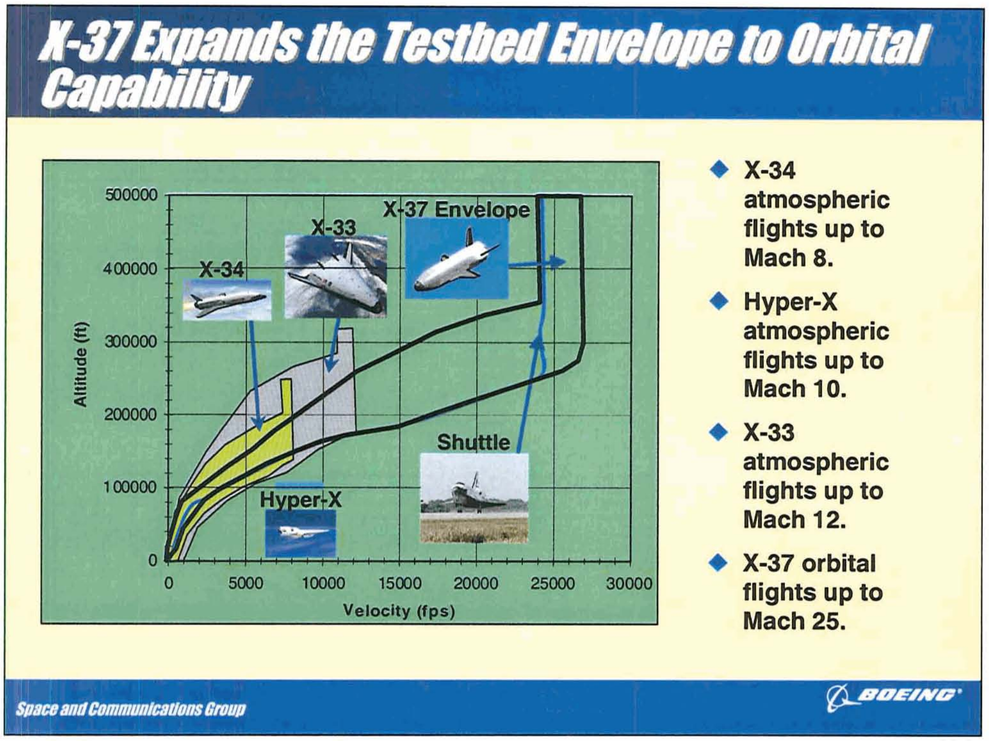
The landing environment provides flight and ground system demonstrations to advance operations technologies. The X-40A atmospheric flights will concentrate on improving autonomous precision landing operations in real wind environments. The X-37 atmospheric drop tests will concentrate on autonomous landing as well as vehicle turnaround ground operations and payload containerized operations. The X-37 reentry drop tests will concentrate on autonomous GPS (Global Positioning System) reentry to precision runway landing and rapid vehicle turnaround.



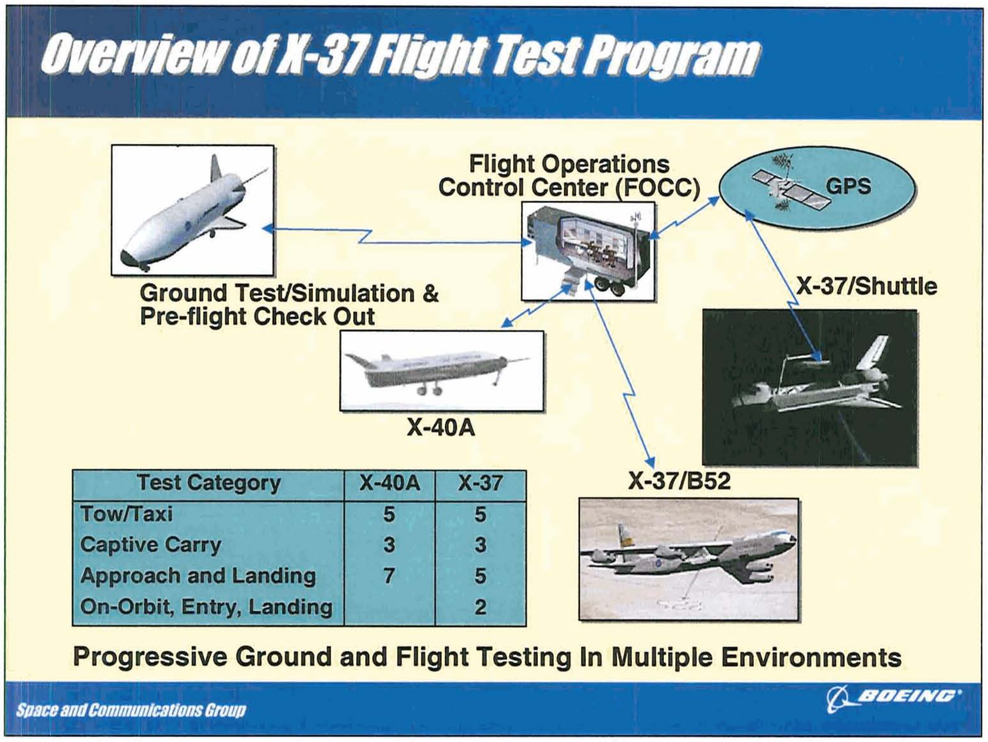
The X-37 is 27.5 feet long – about half the length of the Shuttle payload bay – and weighs about 6 tons. Its wingspan is about 15 feet, and it contains an experiment bay 7 feet long and 4 feet in diameter.

After the X-37 is deployed from the Space Shuttle Orbiter, it will remain in orbit up to 21 days, performing a variety of experiments before reentering the atmosphere, gliding to earth and landing on a conventional runway.

The vehicle provides a platform for both operational and experimental technologies in both on the vehicle and within the payload bay.



The X-37 is designed to demonstrate high-payoff system technologies in relevant test environments beyond those attainable by current X-vehicles. Early flight testing with the X-40A will be used to reduce risk prior to expanded testing with the X-37. Initial orbital and reentry flight-testing emphasizes technology advancement and operations maturation. The X-37 is an enduring testbed supporting follow-on technology validation in earth-to-orbit and on-orbit focus areas for RLVs.



Test Category	X-40A	X-37
Tow/Taxi	5	5
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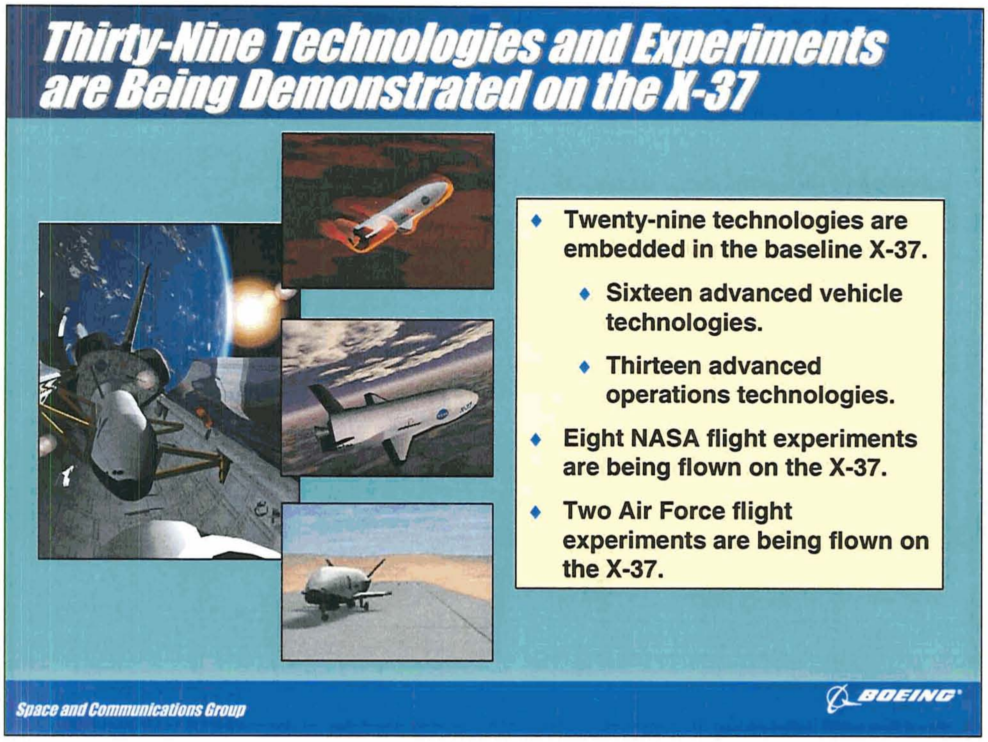
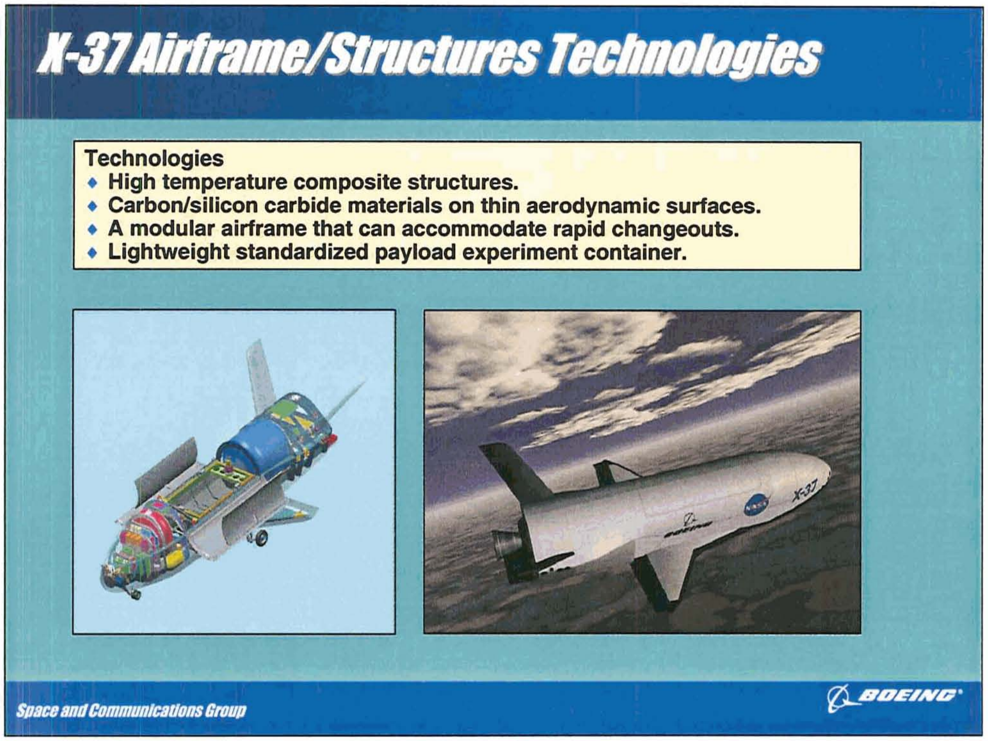
Fourteen flights are planned for the two vehicle configurations: X-40A and X-37. Seven X-40A drop tests, five X-37 drop tests, and two X-37 orbital flights, will demonstrate RLV advanced technologies related to airframe, propulsion, avionics, GN&C, thermal protection, power, mechanical systems, and ground/flight operations.



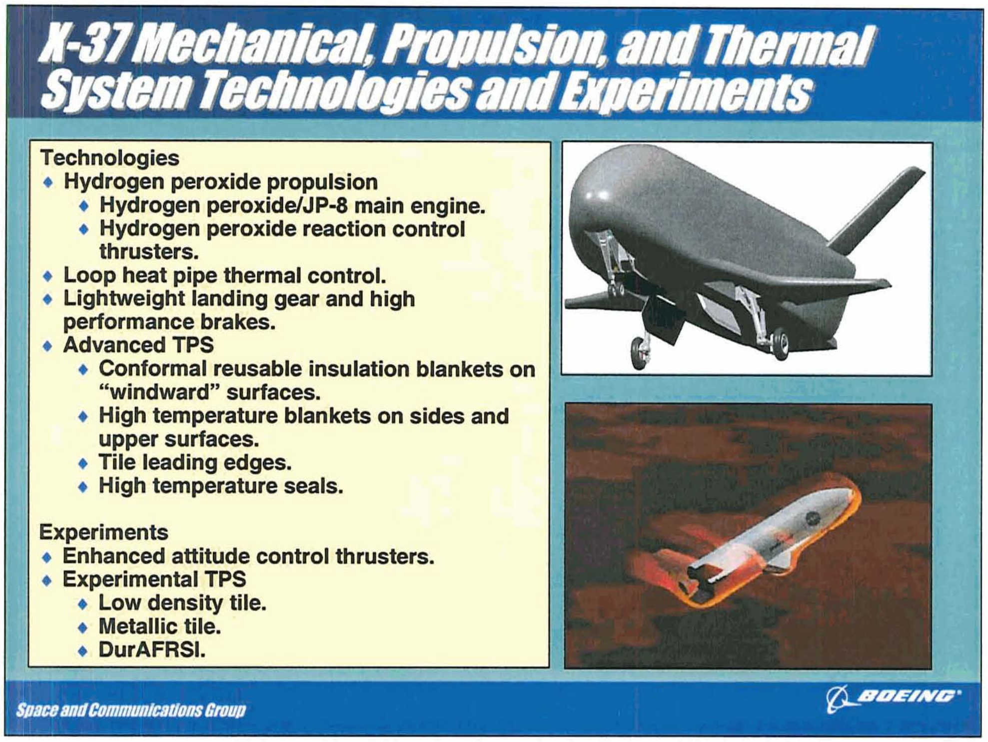
The X-37 vehicle and its ground support currently contain 29 embedded technology demonstrations, eight NASA flight experiments, and two Air Force flight experiments.

These technologies include a modular airframe for easy structure changeouts; hydrogen peroxide/JP-8 propellant system for low-cost operability of the propulsion system; hydrogen peroxide reaction control thrusters; carbon/silicon carbide ruddervators and flaperons for high-temperature control surfaces; a lightweight landing gear; advanced thermal protection materials; a calculated air data system that uses on-board GPS and inertial navigation system data to determine air-speed, attitude, and altitude; a subsurface conformal, electronically steerable, antenna for high-data-rate communications; fault-tolerant control systems capable of autonomous operations; automated rendezvous and close approach; and retractable/deployable solar arrays for on-orbit power. The demonstrations will advance the technology readiness levels (TRL) of these vehicle and operations technologies to support RLV roadmaps.



The primary structures technologies involve incorporating modular components into the X-37 vehicle. The modularity allows various components of the vehicle to be changed out for future technology demonstrations. For example the wings, the tanks, the control surfaces, and the payload container are all being designed to be removable and replaceable.

Additional technologies involve the use of carbon/silicon carbide for high temperature control surface (i.e., flaperons, ruddervators, and body flaps) and graphite/BMI for warm composite surfaces.

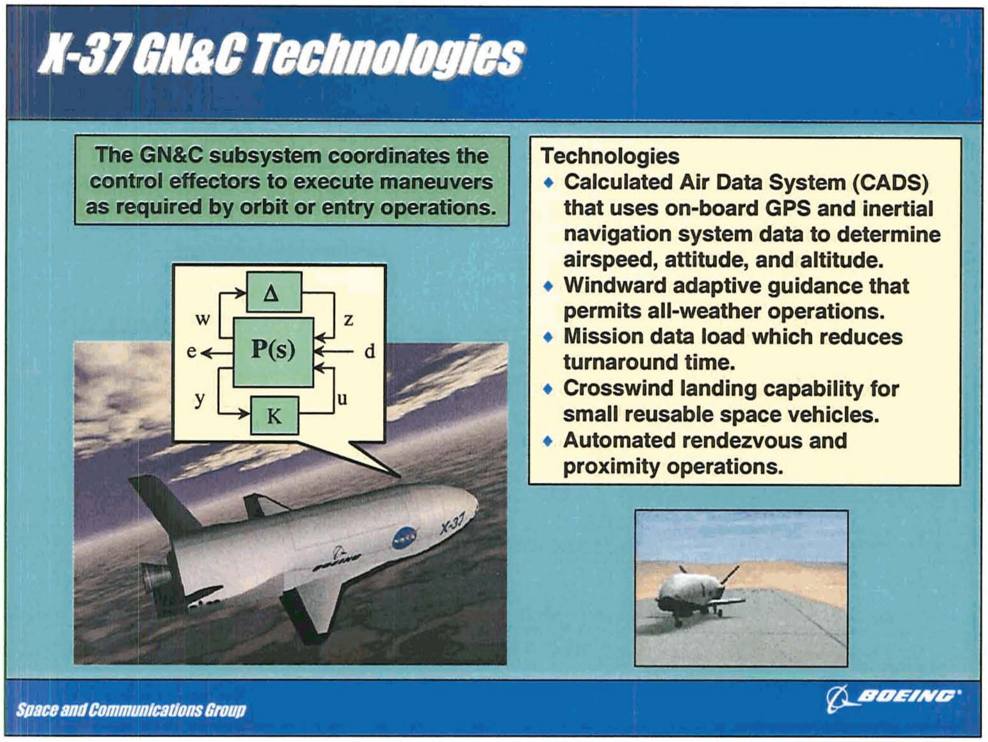


A tremendous focus is being placed on the mechanical, propulsion and thermal protection systems of the X-37.

Key to producing low-cost reusable vehicles is the minimizing of vehicle weight. The use of composite materials for structural components will reduce weight substantially. Additionally, the use of high-performance landing gear and brake systems will further reduce the vehicle weight.

Reusable launch vehicles need simple, safe, low-cost propulsion. As a second stage, small reusable launch vehicles require long on-orbit duration capability. The use of peroxide/JP-8 storable propellants affords the improved operability and permits sustained on-orbit capability which is key to the X-37 design.

The X-37 flight profile will impose upon the advanced thermal protection system technologies, the most severe flight environment of any reusable launch vehicle to date (including the Space Shuttle Orbiter). A number of technologies will be tested on the X-37 including tile leading edges, high-temperature blankets, and metallic TPS.

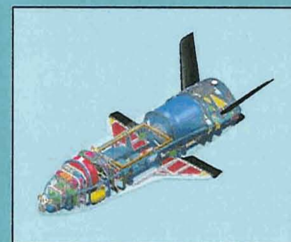


The GN&C subsystems coordinates the control effectors to execute maneuvers as required by orbit or entry operations. Autonomous flight operations with windward adaptive guidance, SRLV crosswind landing, and automated rendezvous and proximity capabilities are the key GN&C technology features. The use of CADS (calculated air data system) and mission data loading are features which will enhance the operations and performance of the X-37.

X-37 Avionics, Power, and Software Technologies and Experiments

Technologies

- Fault-tolerant flight control system to enable autonomous operations.
- Open architecture for flight computing elements to readily accommodate future technology growth.
- Commercial-off-the-shelf hardware and software.
- A dual rate fiber optic bus which provides interfaces to docking controller, experiments, antenna and payload.
- A subsurface, electronically steerable, x-band antenna for high-data-rate communications.
- Small crew FOCC (Flight Operations Control Center).
- Advanced solar arrays that can be deployed in orbit during long duration flights, then stowed for reentry and landing.



Experiments

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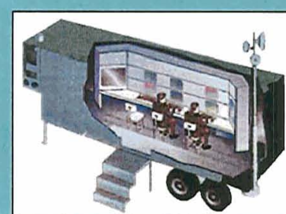

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Avionics technologies include: Open Architecture, Dual Rate Fiber Bus, Low Cost Flush Antenna, COTS HW/SW - Low Devel/Maint Cost, Fault Tolerant Autonomous Ops, Small Crew FOCC, and Solar Arrays.

Experiments include: High Temperature Electronics, High Energy-Density Batteries, NASA IVHM with Boeing IM, and NASA Docking Hardware.

X-37 Technologies and Experiments Support Reusable Launch Vehicle Needs

- NASA/AF Future X Pathfinder X-37 Program enables the maturation of reusable space transportation systems.
  - Technology demonstrations using on-orbit and reentry flight environments.
  - Targeting breakthrough areas in RLV operations and operability technologies.
  - Reusable 2nd stage of a two-stage-to-orbit (TSTO) RLV system.
  - Technologies support NASA and USAF Programs.

Program began July 1999.
Vehicle assembly begins November 2000.
First B-52 atmospheric flight test is in October 2001.
First Shuttle launched flight test is in September 2002.

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The NASA/AF Future X Pathfinder X-37 Program enables the maturation of reusable space transportation systems.

Technologies will be demonstrated on-orbit and in earth reentry flight environments.

RLV operations and operability technologies will be targeted.

The technologies focus on the 2nd stage of a two-stage-to-orbit (TSTO) RLV system and support USAF SMV Program.